AUTOMATIC DETECTION OF NAUSEA USING BIO-SIGNALS DURING IMMERGING IN A VIRTUAL REALITY ENVIRONMENT

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Abstract - **VR (Virtual Reality) system have been widely used for various purposes. However, during people's immersing in a virtual environment it is commonly reported that simulation sickness can occur, and it prevents us from utilizing a VR environment for the wider purposes.**

We constructed controlled a VR environment for analyzing the change of bio-signals during VR immersion, where subjects were requested to find trash cans in the virtual environment within five minutes. Each subject's various bio-signals, which were EEGs from 5 different locations, vertical EOG, Lead I ECG, fingertip skin temperature, photoplethysmogram, and skin conductance level, were measured during experiments. We analyzed and compared the signals, and we found out that the characteristics of 28 signals during nausea were statistically different from when the subjects were at rest, or during the first 30 seconds after the immersion was started.

We parameterized these characteristics and established 12 principal components using principal component analysis in order to reduce the redundancy in those parameters, and constructed an artificial neural network with those principal components. Using the network we constructed, we could partially detect nausea in real time.

Keywords – **VR (Virtual Reality), Simulation Sickness, Bio-Signal, Principal Component Analysis, Artificial Neural Network**

I. INTRODUCTION

VR (Virtual Reality) technology has been used for various applications, such as flight simulation [1], driving simulation [2], and rehabilitation system for patients who suffer from acrophobia [3], etc.

However, during immerging in a virtual reality environment, many people reported simulation sickness, such as nausea, vomit, headache, etc. This simulation sickness prevents virtual reality from being used widely. Simulation sickness has been studied by many researchers. For example, Regan et al. studied the side effects of immersion in virtual reality [4]. We also note Regan et al.'s article about reducing the side effects induced during immersion in virtual reality using Hyoscine Hydrobromide [5].

Our research focuses on the system that can give feedback when it finds a subject who in experiencing a VR environment feels nausea; such a system should also minimize the inconvenience by use of electrodes. In order to reduce simulation sickness, the system measures and analyzes the bio-signal of the subject who is immerged in a virtual reality environment, finds out by using artificial intelligent system whether the subject feels nausea or not, and gives a feedback to the subject when the system detects that the subject feels nausea. To minimize the inconvenience caused by the electrodes special kinds of electrodes should be developed, such as an EEG and EOG electrode equipped in HMD (Head Mounted Display), and a skin temperature and phoplethysmogram electrode equipped in glove. The primary aim of this study is to give a preliminary guide for the research.

II. METHODS

1. *Experiment for analyzing the bio-signal of a subject who is immerging in a VR environment*

1.1 Subjects

45 subjects who were 18-26 year-old college students participated in the experiment. (25 Male, 20 Female, Mean 21.9 yr.) All of these subjects had intact vestibular function and were not receiving medication at the time.

1.2 Equipment

The VR system used for this experiment was a 3D visual and auditory environment generator (3 channels, resolution: 3840x1024, constant 30 frames/sec), constructed by the KIST (Korean Institute of Science and Technology).

Various kinds of bio-signal electrodes were attached to the subjects. These electrodes measured EEGs from 5 different locations Fz, Cz, Pz, O1, O2), vertical EOG, Lead I ECG, fingertip skin temperature, photoplethysmogram, and skin conductance level. Using MP-100 by BIOPAC Co. we sampled the bio-signals of all 10 channels in 200Hz sampling rate and stored them in a computer.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Automatic Detection of Nausea Using Bio-Signals During Immerging in A Virtual Reality Environment	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Interdisciplinary Program in Medical and Biological Engineering Major Seoul, Korea	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.	
Abstract	
Subject Terms	
Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU
Number of Pages 4	

TABLE I
PERIODS USED FOR DATA ANALYSIS

Periods	Details
Before VR (Period I)	From when the experimental setting is completed for each subjects to when VR simulation starts (1 minute)
Right after VR (Period II)	For 30 seconds after VR simulation starts
During VR (Period III)	From 30 seconds after VR simulation starts to the end of VR simulation

1.3 Procedure of experiment

Before each subject experienced the VR environment his/her bio-signals were measured for 1 minute, and he/she experience VR environment for 5 minutes each.

The subjects were requested to find trashcans in the virtual background of KIST buildings and to report nausea to us orally whenever the felt sickness.

2. Data Analysis

29 out of the total 45 subjects reported nausea at least once. We analyzed the signals of these 29 subjects. The analysis was performed within 3 different periods (TABLE I): before experiencing VR simulation for a minute; right after VR started for 30 seconds; and from 30 seconds after VR started to the end of VR.

For Period III nausea and normal period were classified. The nausea period is within 3 seconds at the time when a subject reports nausea, and we divided the whole period III into 3-second periods. [Normal periods are those 3-second periods that do not contain any nausea points.]

3. Feature Extraction

We extracted features in each period from each subject's bio-signal as in the TABLE II.

Firstly, we calculated the relative power of each frequency band. These ranged from theta (5-8Hz), alpha (9-13Hz), beta (14-30Hz), and gamma (31-50Hz) from EEGs in 5 different locations. The relative power of each frequency band is related with mental activities [6].

Secondly, we calculated the standard deviation of EOG. Eye blink frequency is related with highly cognitive mental process [7]. The standard deviation of vertical EOG contains eye blink information.

Thirdly, the mean of R-R intervals was calculated from raw ECG using BIOPAC MP-100 software. Heart rate is related with mental response. The ANS (autonomic nervous system) causes the heart to beat faster or slower according to mental response.

TABLE II
ANALYZED FEATURES

Electrodes	Features
EEGs from 5 different locations (Fz, Cz, Pz, O1, O2)	Relative power of each frequency bands - Theta (5-8Hz) - Alpha (9-13Hz) - beta(14-30Hz) - gamma (31-50Hz)
EOG	Standard deviation
ECG	R-R interval mean
Finger tip skin temperature (SKT)	- mean - standard deviation
Photoplethysmogram (PPG)	- mean - standard deviation
Skin conductance (SCL)	- mean - standard deviation

Fourthly, we calculated the mean and standard deviation of fingertip temperature. Skin temperature is linked to sympathetic arousal that in turn affects vasoconstriction. The latter affects the perfusion of blood, particularly in extremities such as the fingers and toes. Typically, sympathetic arousal leads to increased vasoconstriction, which causes a reduction in blood volume and hence to a cooling effect on the skin. [8]

Fifthly, we calculated the mean and standard deviation of photoplethysmogram. Photoplethysmogram measures blood volume in fingertip.

Sixthly, we calculated the mean and standard deviation of skin conductivity. The latter has been recognized as distinctively sensitive to transitory emotional states and mental events, while often remaining more or less independent of other measures such as muscle tension and skin temperature.[8]

4. Feature Analysis

In order to detect nausea from each subjects in real-time the parameters used for detection should be independent of the characteristics of the subjects; thus the features should be duly modified for this purpose. Each subject has a different base line for each feature, which makes it difficult for an artificial neural network (ANN) to be trained. Therefore we defined the base line value of each features as feature values in Period I or Period II according to the characteristics of the features. The ratios of feature values in the 3-second time window to the base line are selected were parameters (TABLE III).

We analyzed these parameters with T-test and obtained a result that the parameter values when a subject feels nausea are statistically different from the values in normal state. ($p<0.05$)

TABLE III
RELATED PERIODS FOR EACH FEATURE

Features	Related period according to their characteristics
All EEG frequency bands, PPG Standard deviation	Period I
PPG Mean EOG Standard deviation GSR Mean GSR Standard deviation Heart Beat Rate	Period II

5. Construction of an artificial neural network

Training vectors were constructed from parameters in both nausea and normal period. Nausea is a scarce event compared with a normal event so we repeated nausea vectors equivalent to the normal vectors. There exists some inherent redundancy in 28 parameters because each frequency band in the EEGs has similar information for nausea. In order to eliminate this redundancy principal component analysis was performed. We obtained 12 principal vectors which could be used as an input vector of the artificial neural network.

We trained 2-layer feedforward neural network whose hidden layer has 10 nodes with standard error backprogation algorithm. The minimum mean square error we got was 0.092.

6. Construction of real-time nausea detection system

At first we collected parameters of Period I and Period II - that is 30 seconds after the start of VR. After they were collected a parameter for the previous 3 seconds could be calculated per second. Ratios of each parameter calculated to Period I or Period II can be calculated; these ratios would be transformed with a transform matrix attained from principal component analysis of training vectors. Those transformed ratios would be inputted to the ANN which we constructed, and we would find out whether the signal is related with nausea or not.

III. RESULT AND DISCUSSION

We tested the validity of the real-time nausea detection system with the entire time series of each subject. Fig. 1 shows the comparison between the system output and actual nausea points. As seen in the picture, the ANN output and actual nausea points are not identical. The reason is because nausea was reported verbally so that the actual points could be inaccurate, and the nausea level is not standardized for each subject. So some subjects may report nausea when light symptom occurs while others may report nausea only when heavy symptoms occurs. Another factor is that the ANN

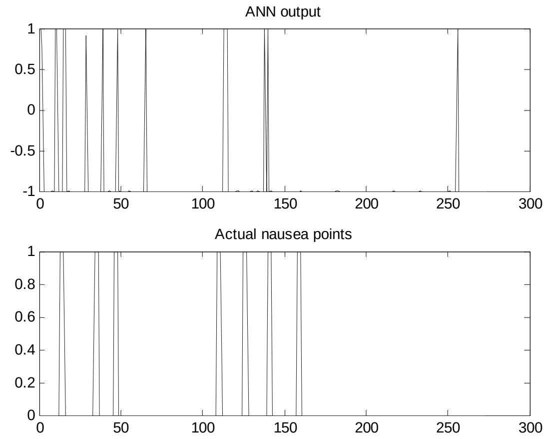

Fig. 1 Comparison of ANN out put with Actual Nausea points

parameters we used as inputs were not very good ones; as a consequence nausea might not be detected very well. The minimum mean square error of the ANN training set was 0.09. This could be improved if we chose better parameters.

In the future we aim to construct a better experiment system and to study other parameters for the better performance of the nausea detection system.

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